# Nuclear Star Clusters and Black Holes


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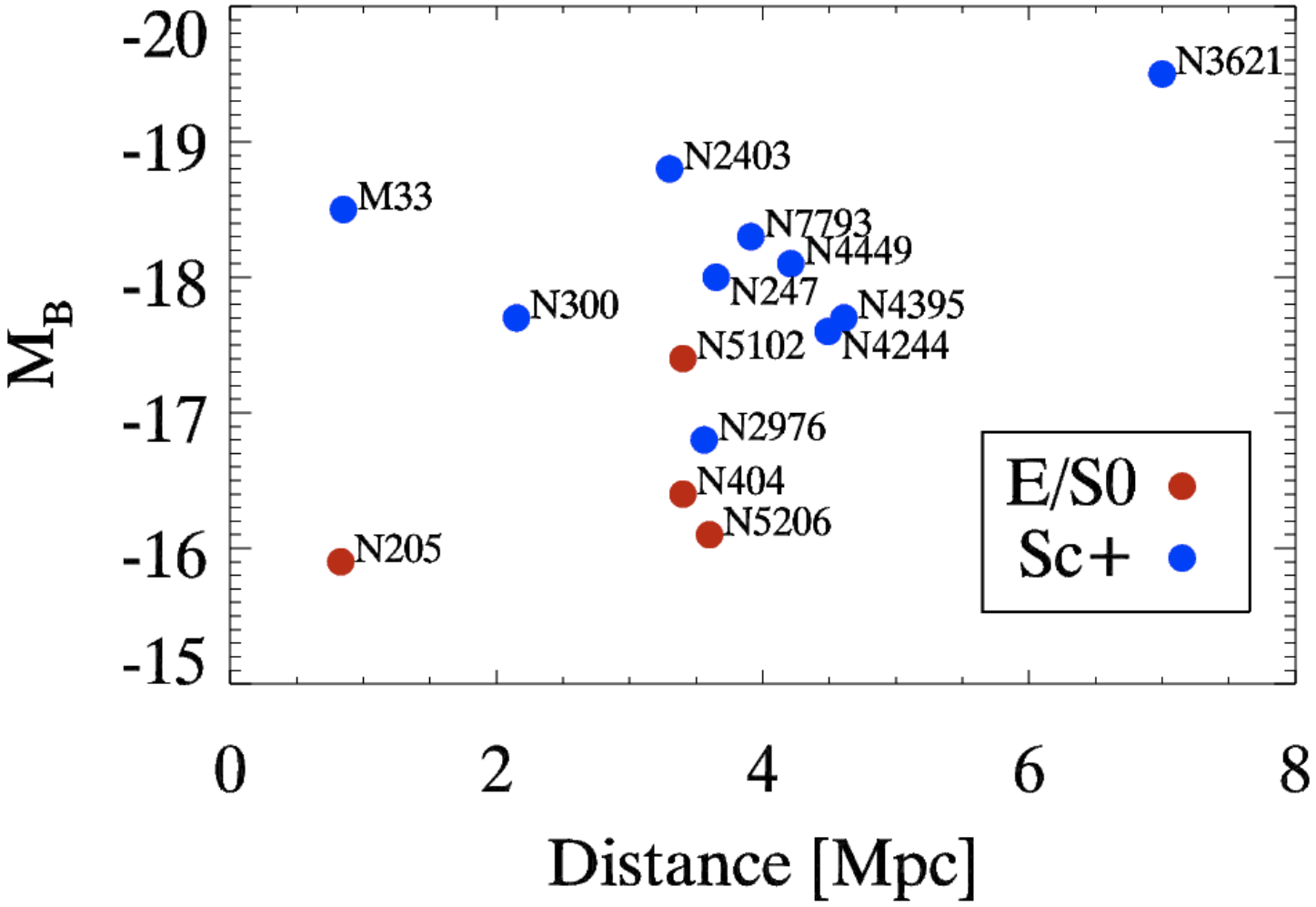
HST image of NGC 3621

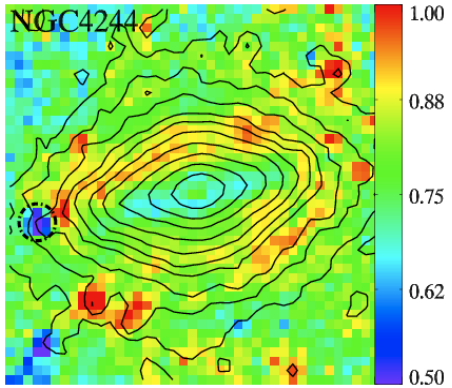
# Nearby Nuclear Star Clusters




Seth+ 2008b, Seth+ 2010, Neumayer+, *in prep*

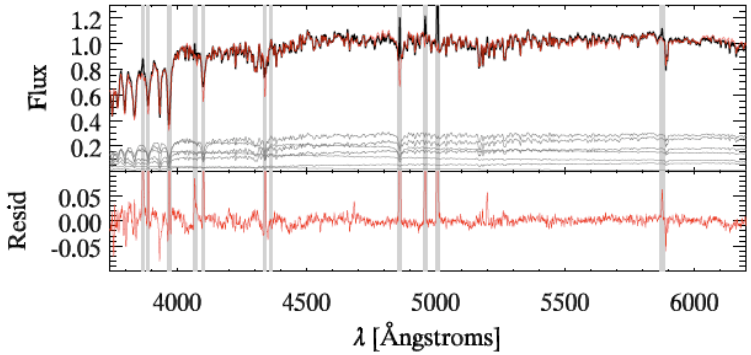
# Resolving Nuclear Star Clusters

1) Morphology



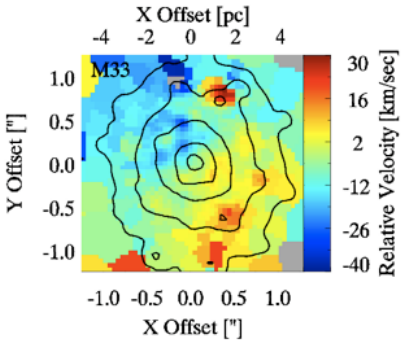

HST Imaging

2) Stellar Populations




Optical Spectra (Magellan, MMT, VLT)

3) Kinematics




Adaptive Optics IFU spectra (Gemini, VLT)


The Formation of
Nuclear Star Clusters

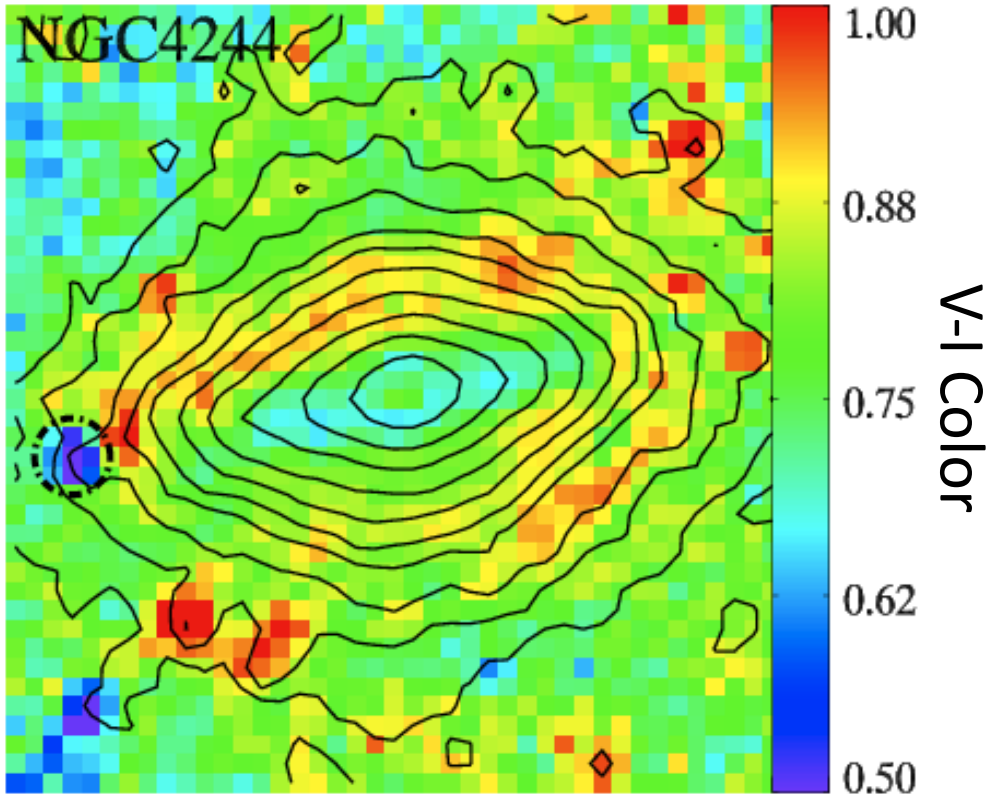
# Evidence for episodic accretion

Morphology

In edge-on spirals:

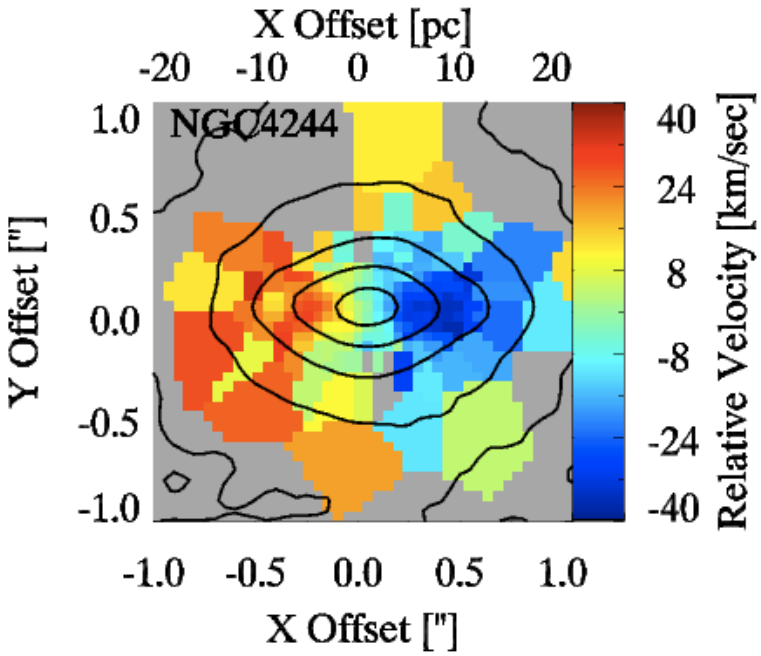
- Flattened clusters *aligned with galaxy disks.*
- Bluer disks/rings near midplane
- Multiple pops/ continuous SFH from spectra

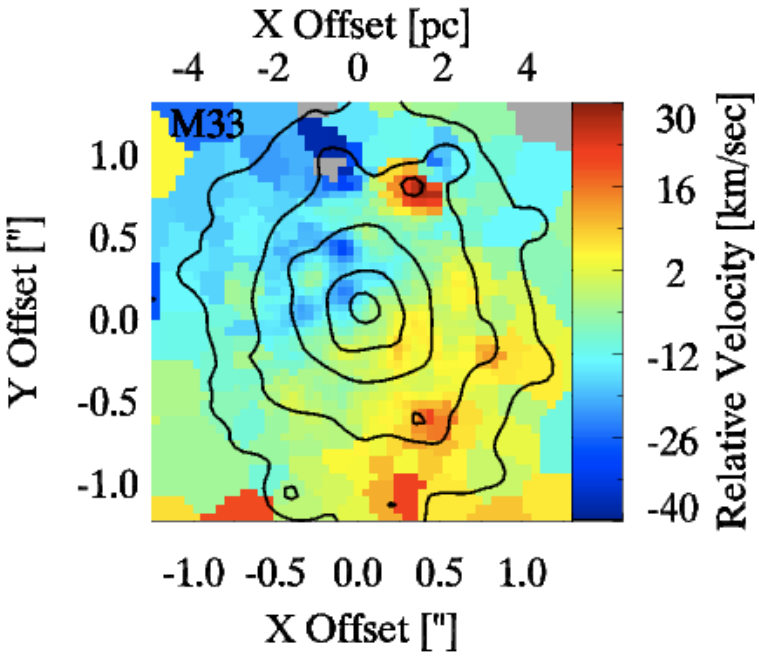
Central 40 pc of NGC4244




Seth+ 2006

# Rotation Dominated

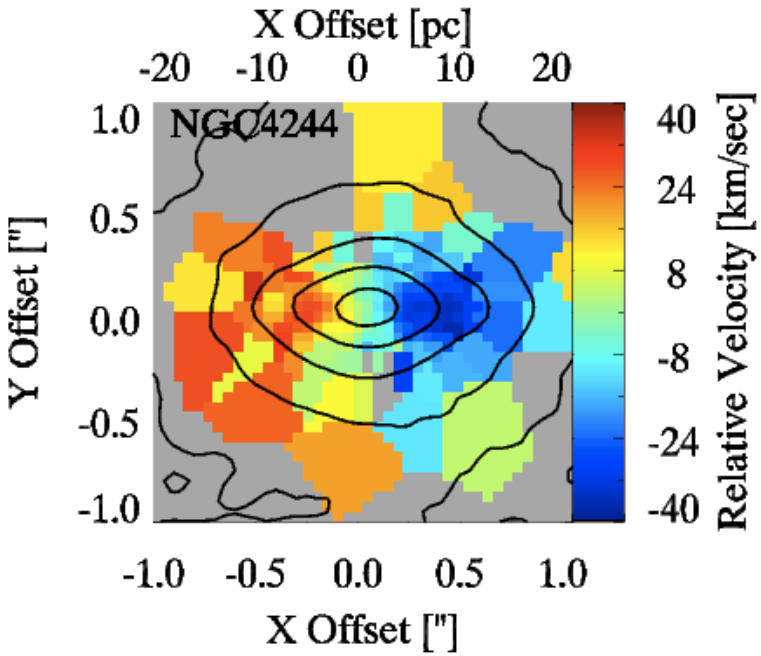



Seth+ 2008b

See also, Milky Way (Trippe+ 2008, Schoedel+ 2009)

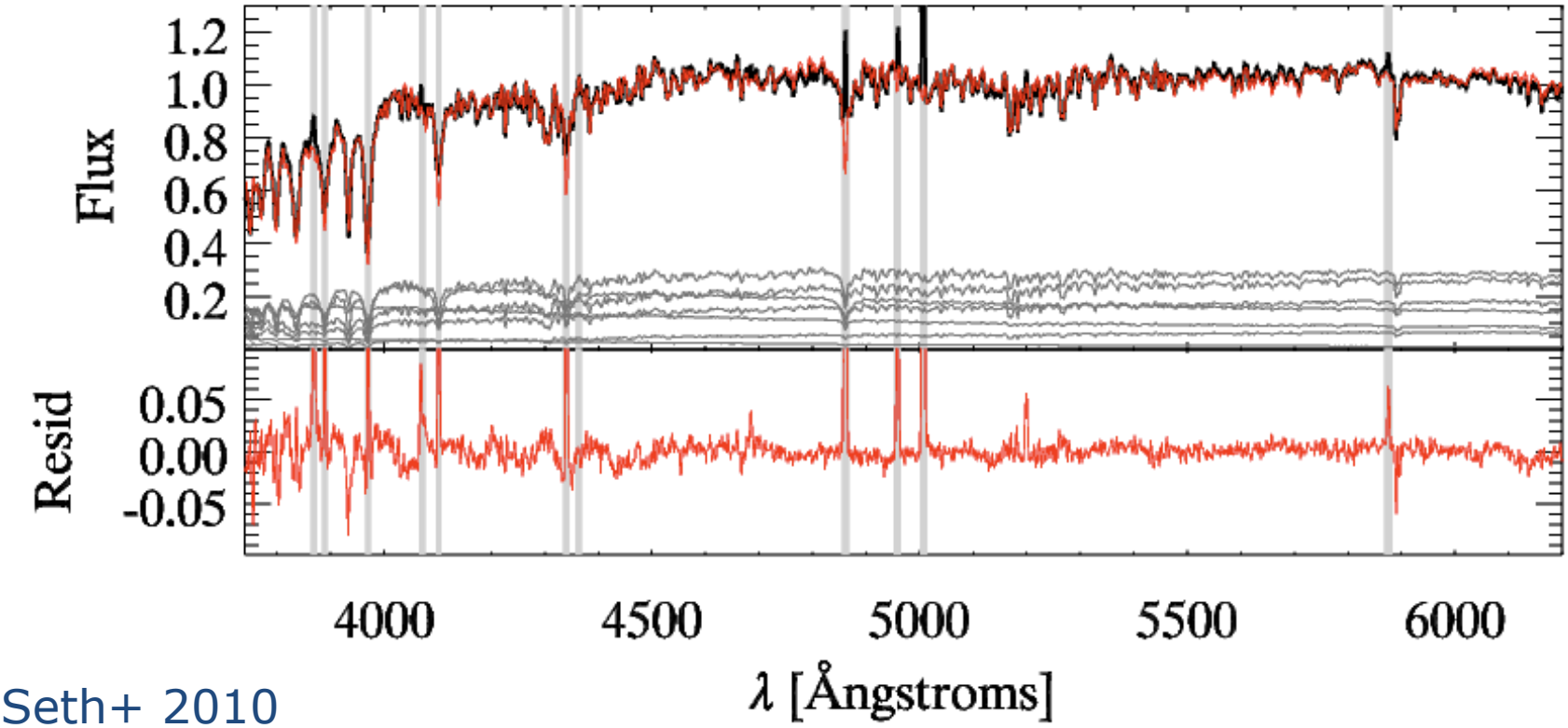
# Episodic Disk Accretion




- Accretion of gas or stars from the galaxy into a disk
- Older stars get puffed up by accretion event
- Recurs ~100 Myr
- Cluster or Gas Accretion? See Markus Hartmann's talk tomorrow!

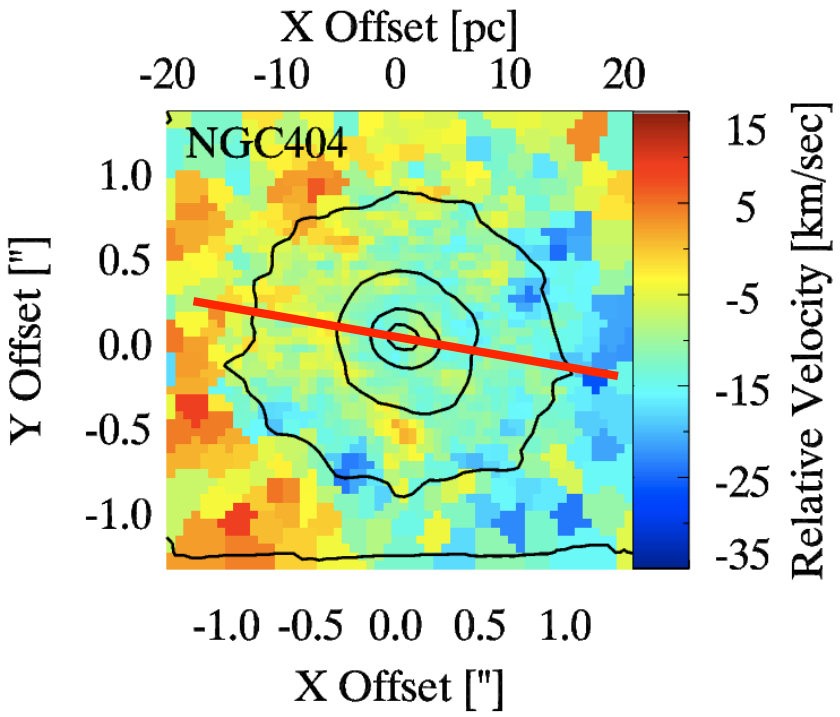
# Evidence for Merger Accretion

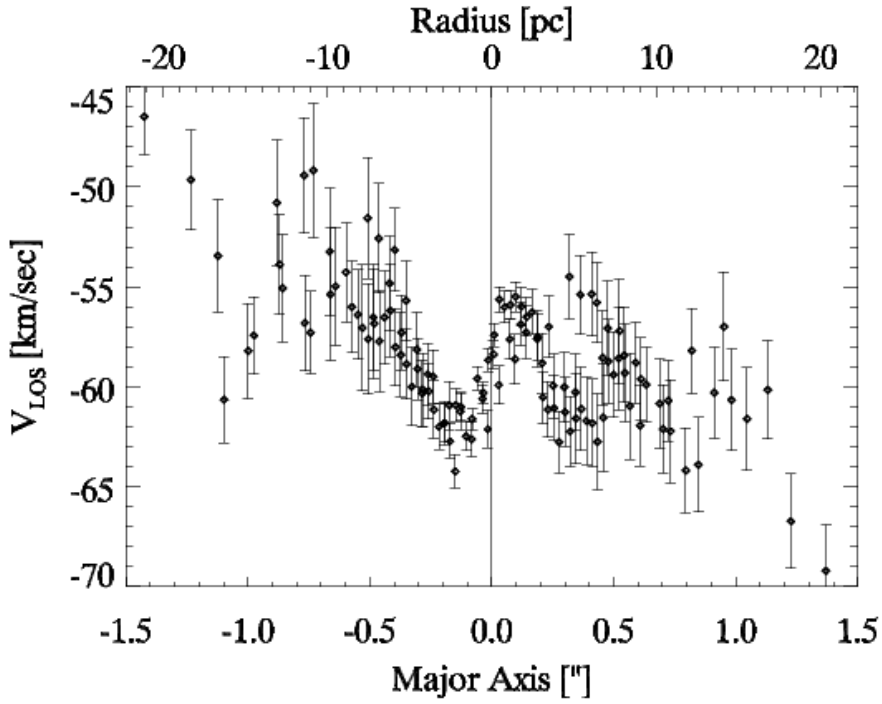
- NGC404 nearest S0 galaxy ~$10^9$ $M_\odot$.
- Galaxy is old (>10 Gyr) (Williams+ 2010)
- Nuclear star cluster has dominant ~1 Gyr old population (50% of mass)
- HI Gas in outskirts merger ~1 Gyr ago! (del Rio+ 2004)




Seth+ 2010

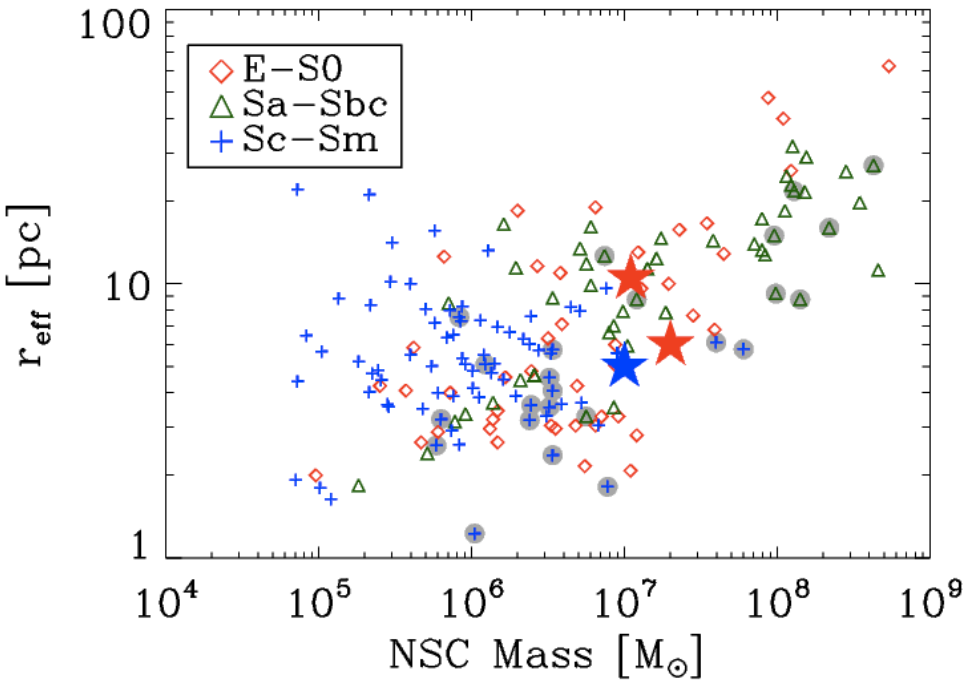
# Evidence for Merger Accretion



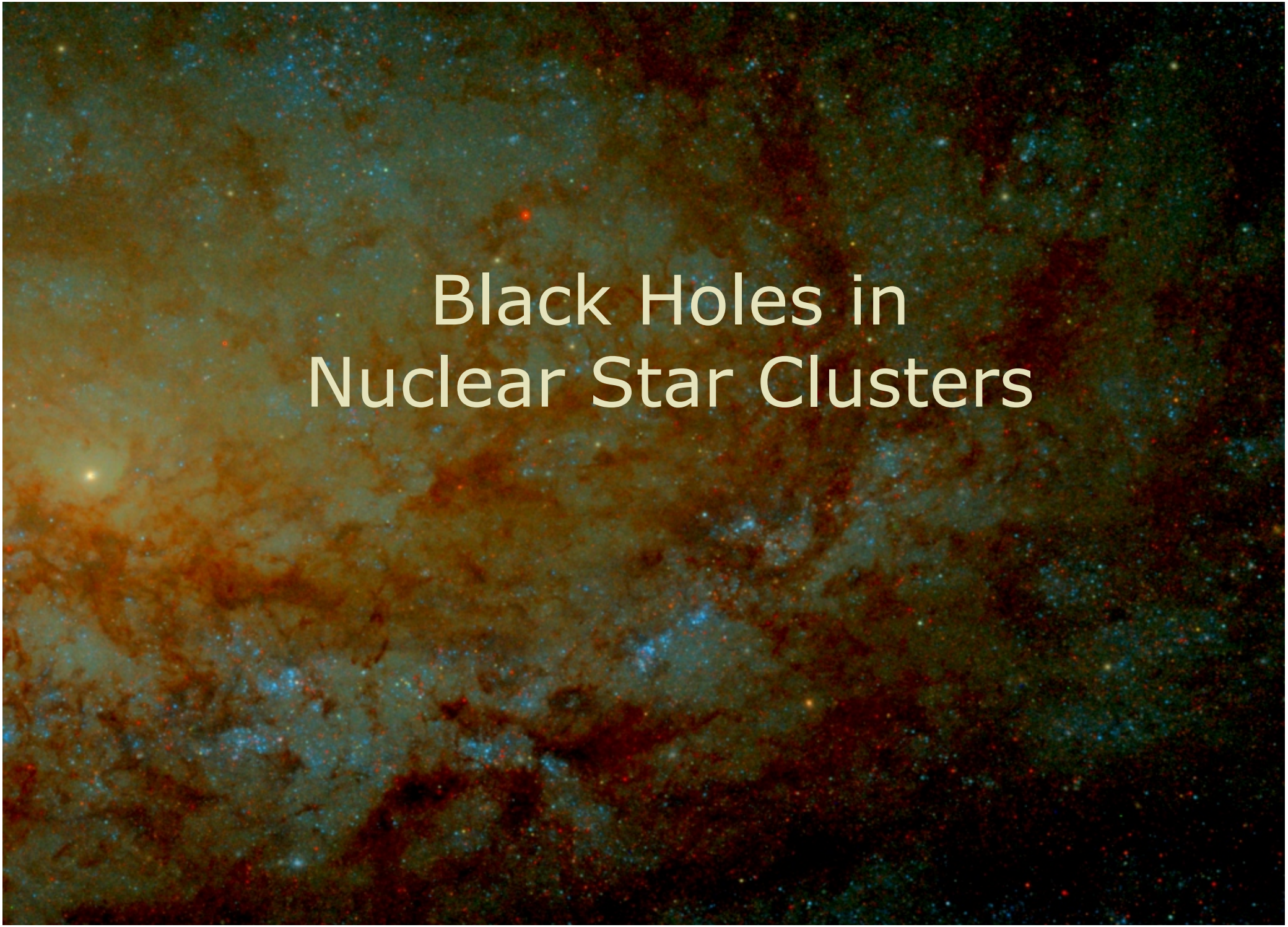

Seth+ 2010

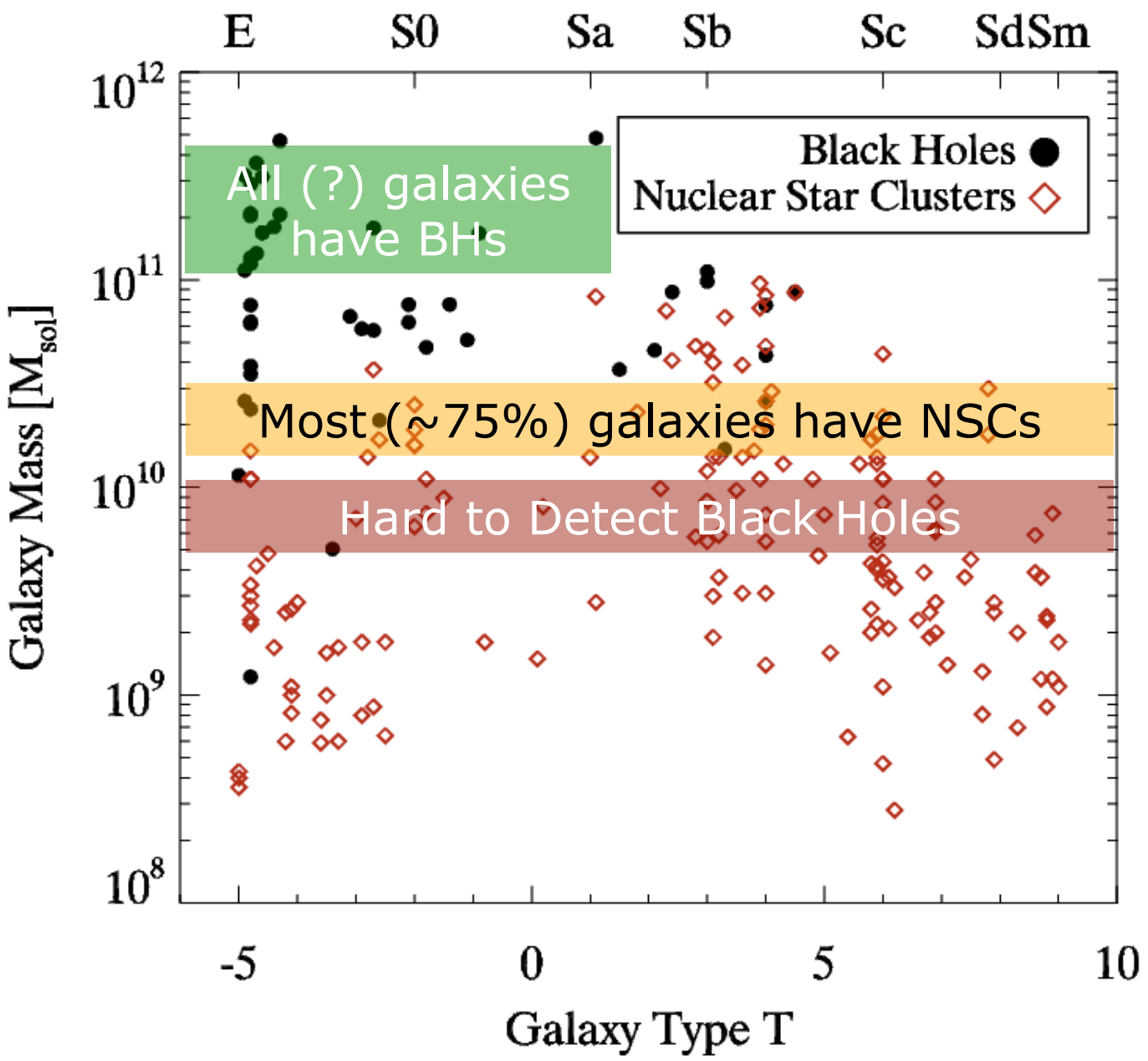
# Two Pathways To Similar Objects



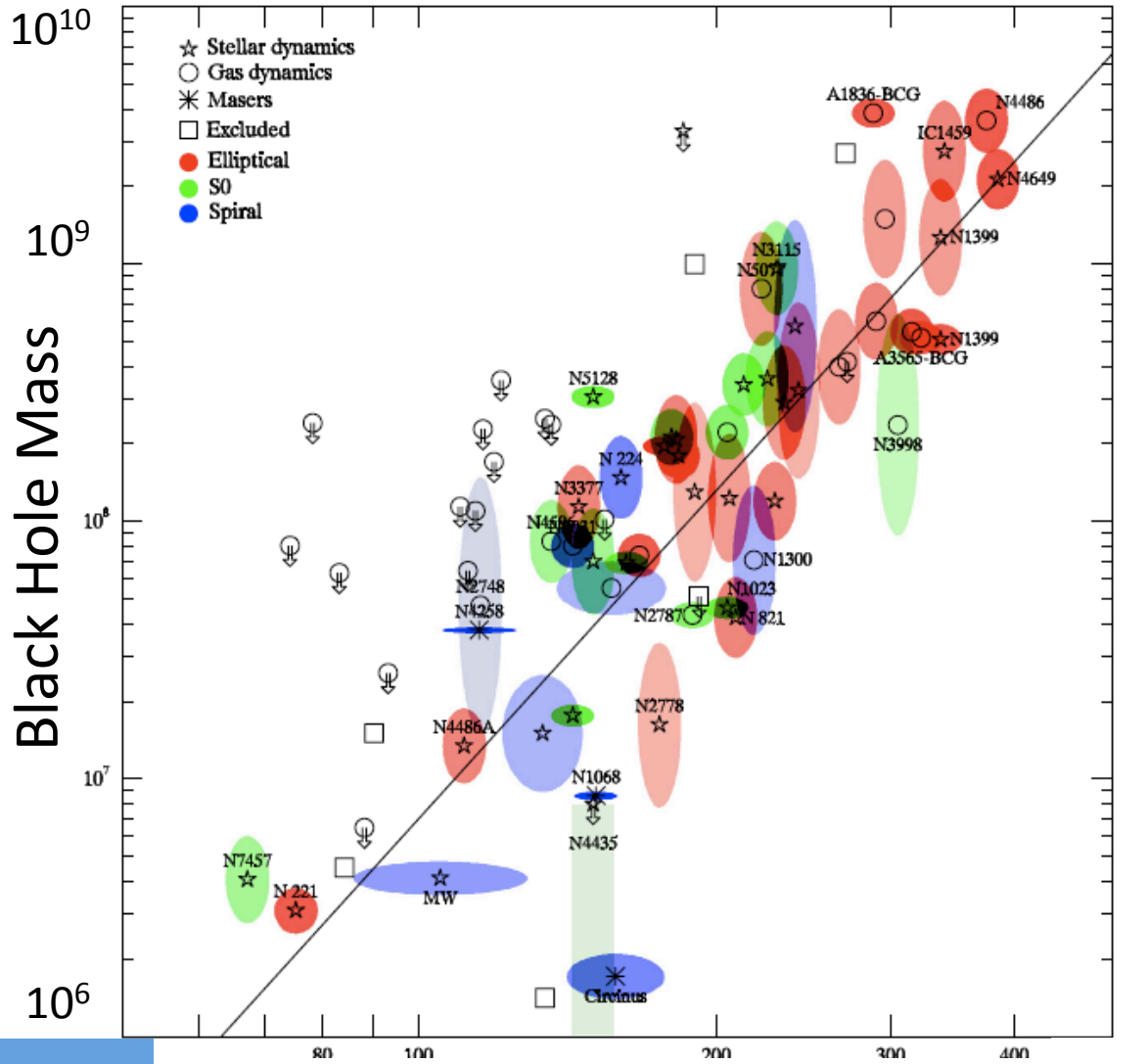

Episodic Disk Accretion vs. Merger Accretion

- Primary difference is the stellar population.
- Both rotate strongly.
- Scaling relations?


Black Holes in
Nuclear Star Clusters




Data from: Böker+ 2002, Côté+ 2006, Carollo+ 1998-2002, Seth+ 2006, 2008a, Gültekin 2009




Our Galaxy Sample

Gültekin+ 2009

# Close look at NGC 404

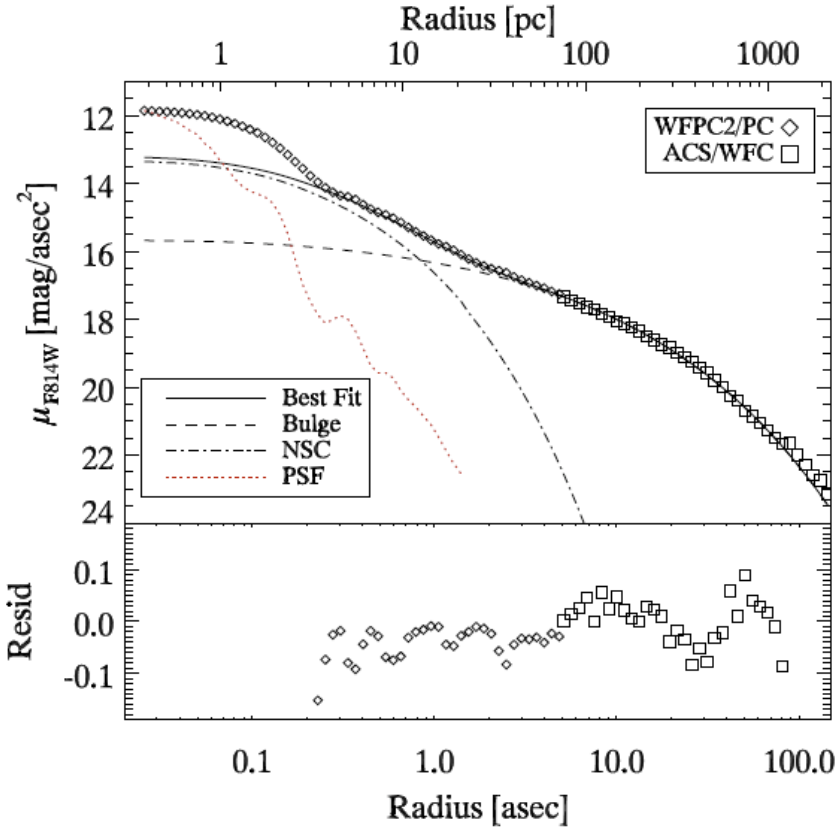
GALEX Thilker et al. 2010

- Nearest S0 galaxy
  D=3Mpc, σ=35km/s
- Some evidence for an accreting black hole:

✔ LINER like nucleus
✔ compact X-ray source
✔ High excitation lines in Mid-IR
✔ variable UV emission
✔ compact dust emission

Ho+ 1997, Eracleous+ 2002, Satyapal+ 2004, Maoz+ 2005, Seth+ 2010

# Dynamical black hole detection



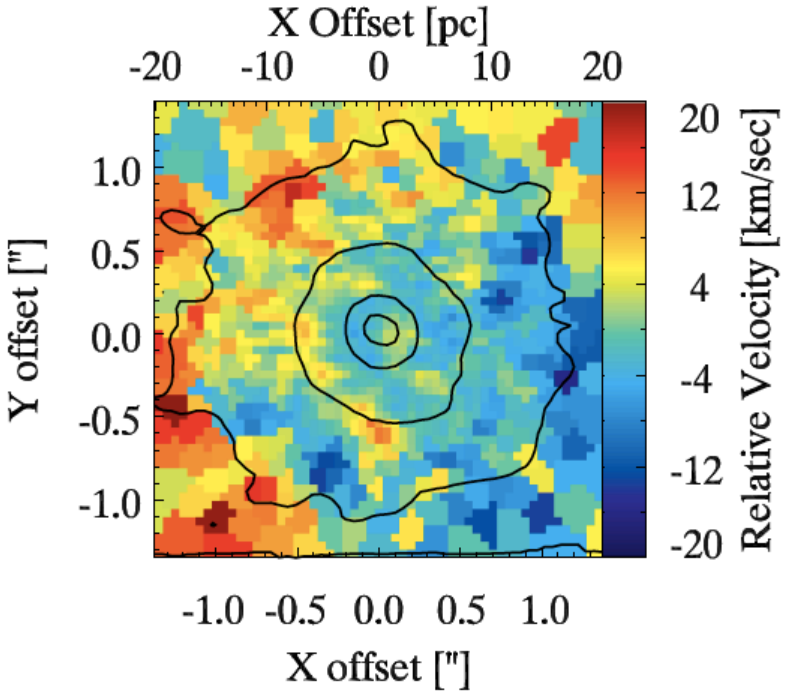

Seth+ 2010

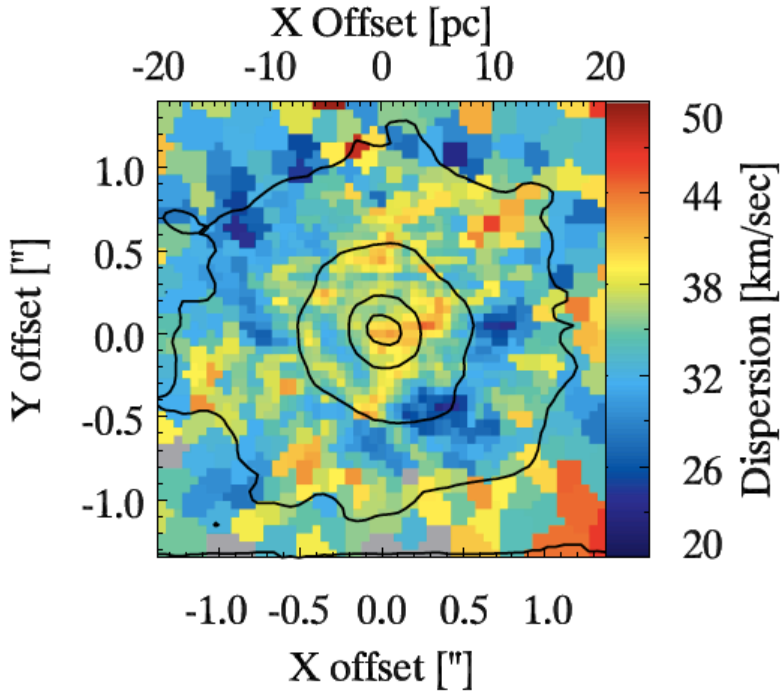
Ingredients:

1) Stellar Mass Profile
   - Luminosity Profile
   - Mass-to-light ratio

2) Dynamical Tracer

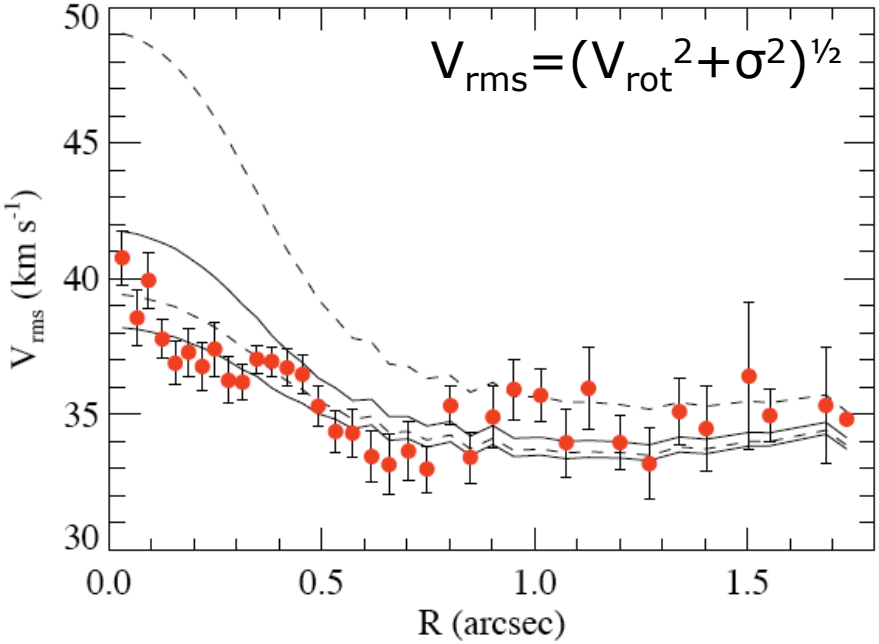
# NGC404 - Stellar Kinematics



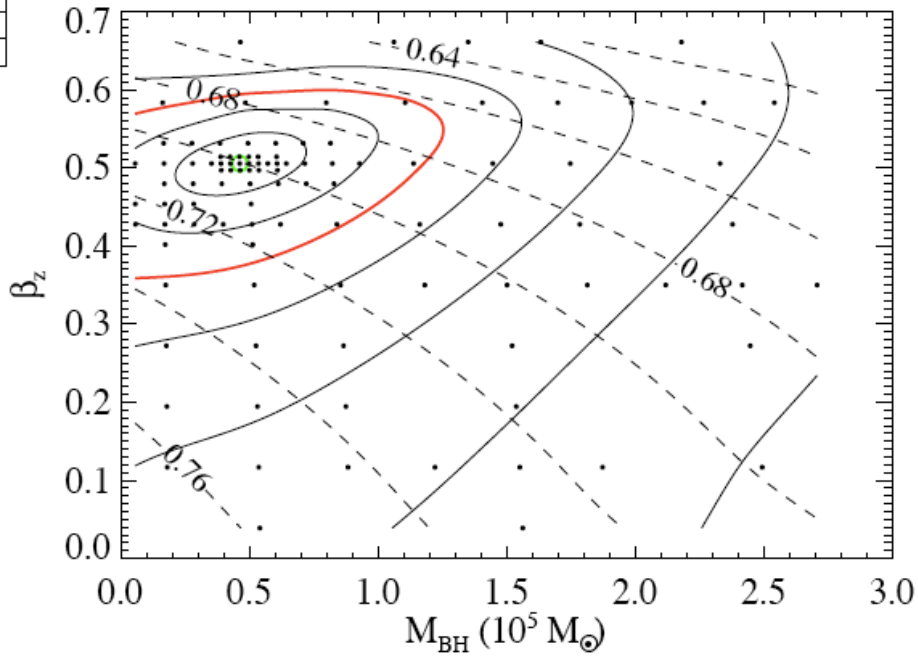




Seth+ 2010

# NGC404 - Stellar Kinematic Model

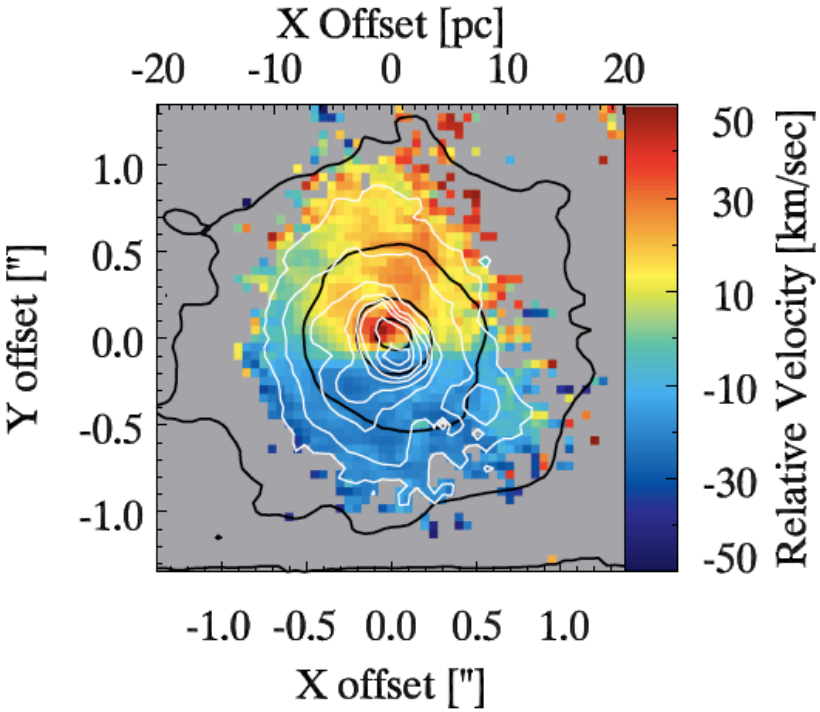


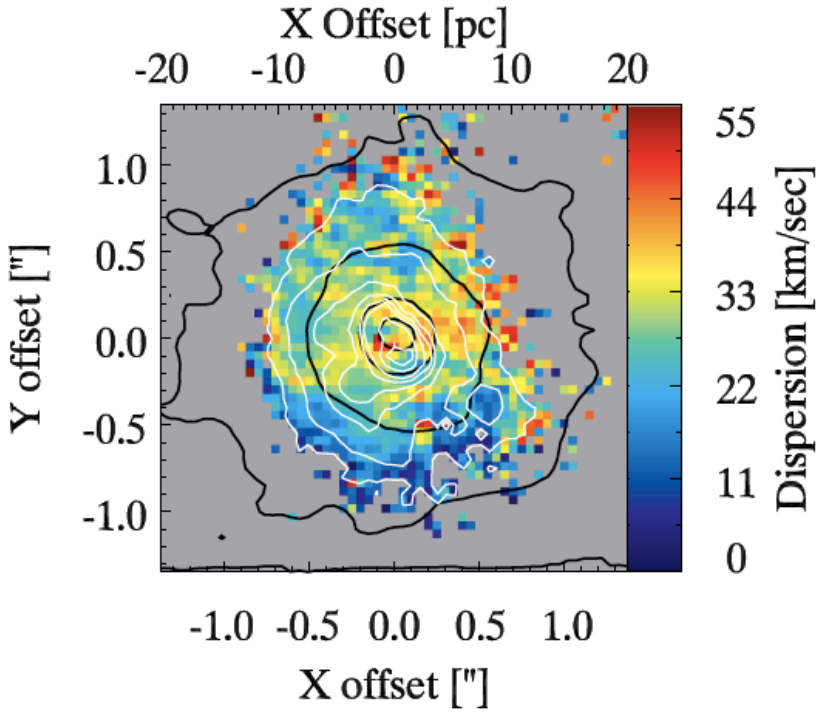

- Jeans anisotropic model
- Fit $M_{BH}$, $\beta_z$, M/L
- $M_{BH} < 1\times10^5\ M_\odot$ ($\sim 0.5\times10^5\ M_\odot$)




Seth+ 2010

# NGC404 - $H_2$ Gas Kinematics




Seth+ 2010

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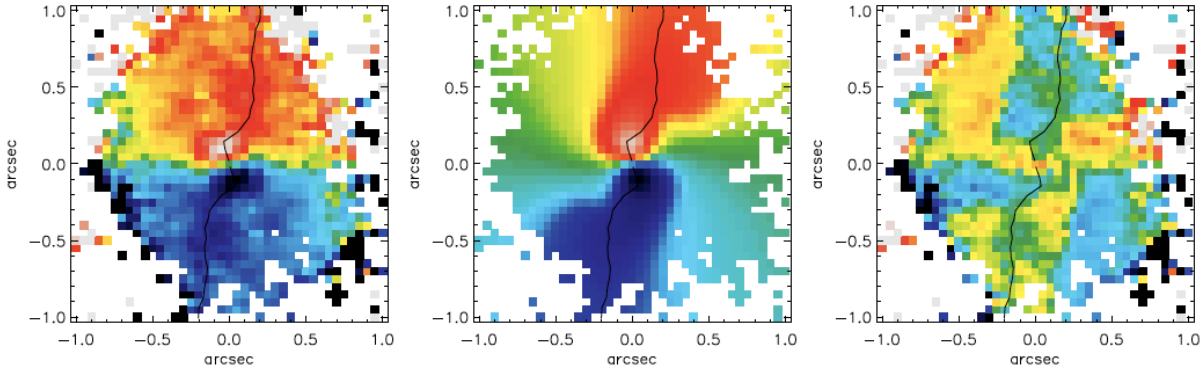
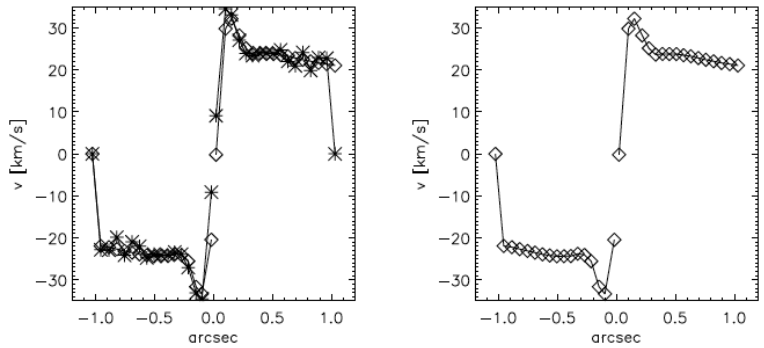
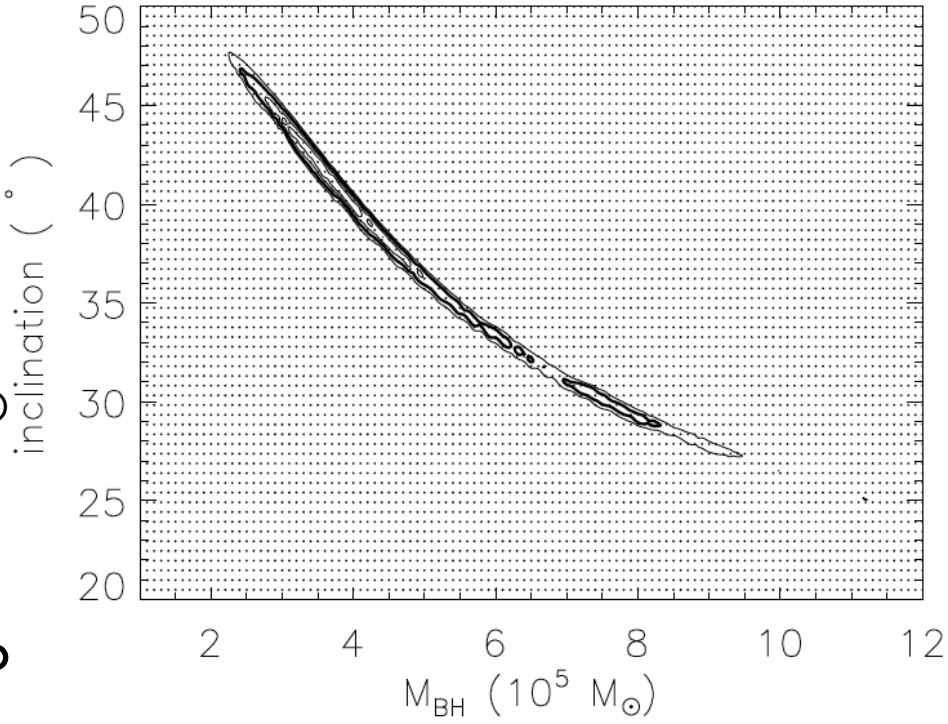



- $M_{BH} \sim (4.5 \pm 3) \times 10^5\ M_\odot$
- Degeneracy due to $v_{rot} \sim \sqrt{M_{BH}} \times \sin(i)$
- Inclination i~37°±10°




NGC 3621 - Sd galaxy
Bulge-less spiral

# NGC 3621 - Sd galaxy

NGC 3621 / ESO

- Bulge-less spiral
- hosts nuclear cluster…
- …plus detected AGN
  - in MIR (Satyapal et al. 2007)
  - and X-rays (Gliozzi et al. 2009)
- $M_{BH} > 2 \times 10^4\ M_\odot$
- $M_{BH} < 3 \times 10^6\ M_\odot$
- SINFONI data resolve the cluster
- Can dynamically detect $M_{BH} \sim 3 \times 10^5\ M_\odot$

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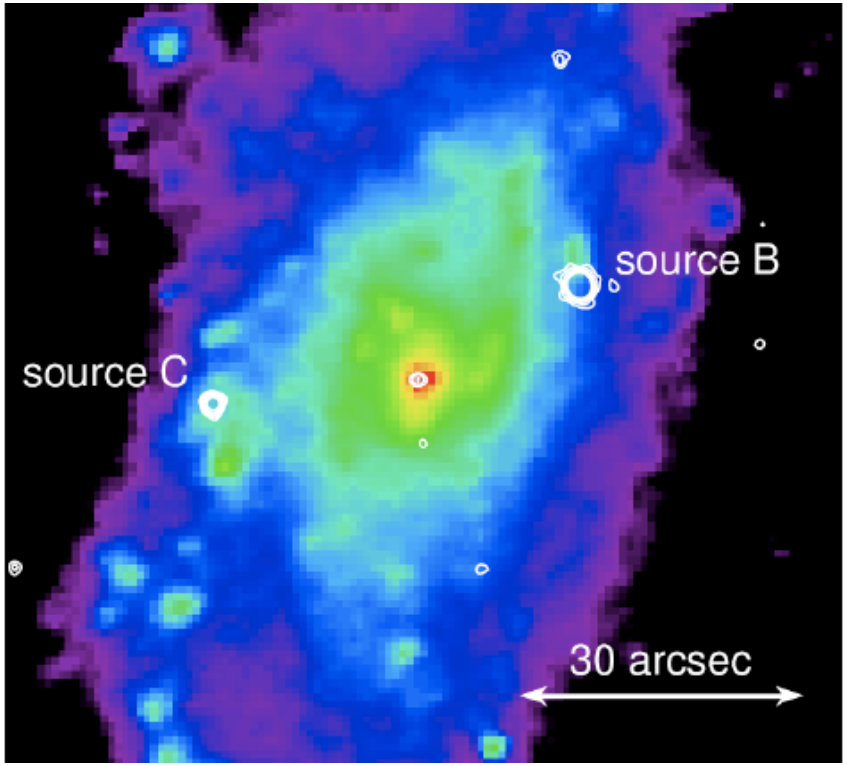


(Gliozzi et al. 2009)

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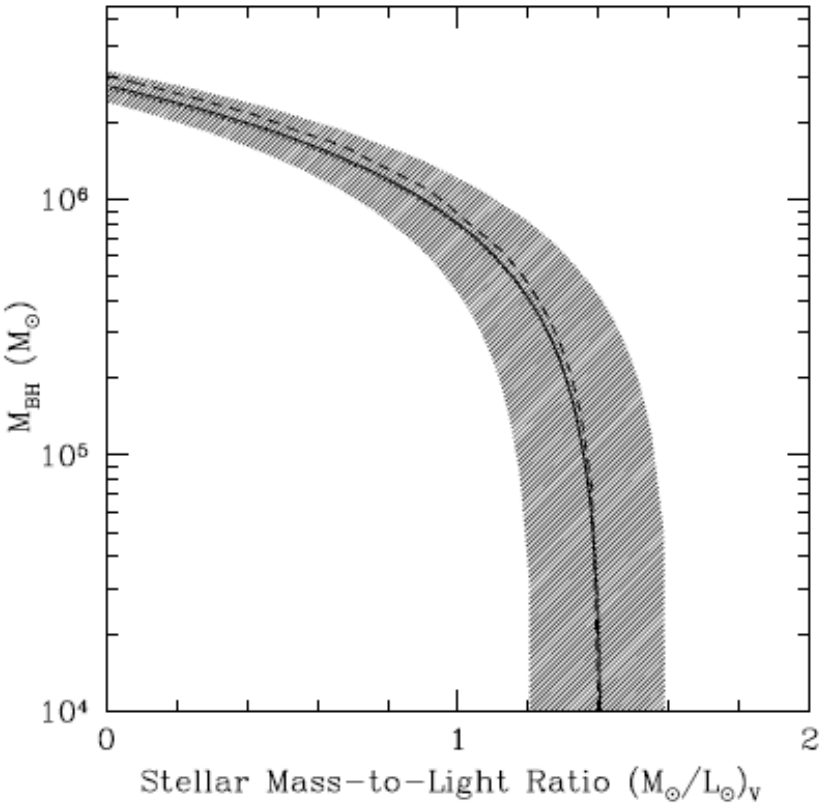


Barth et al. 2009

Barth et al. 2009

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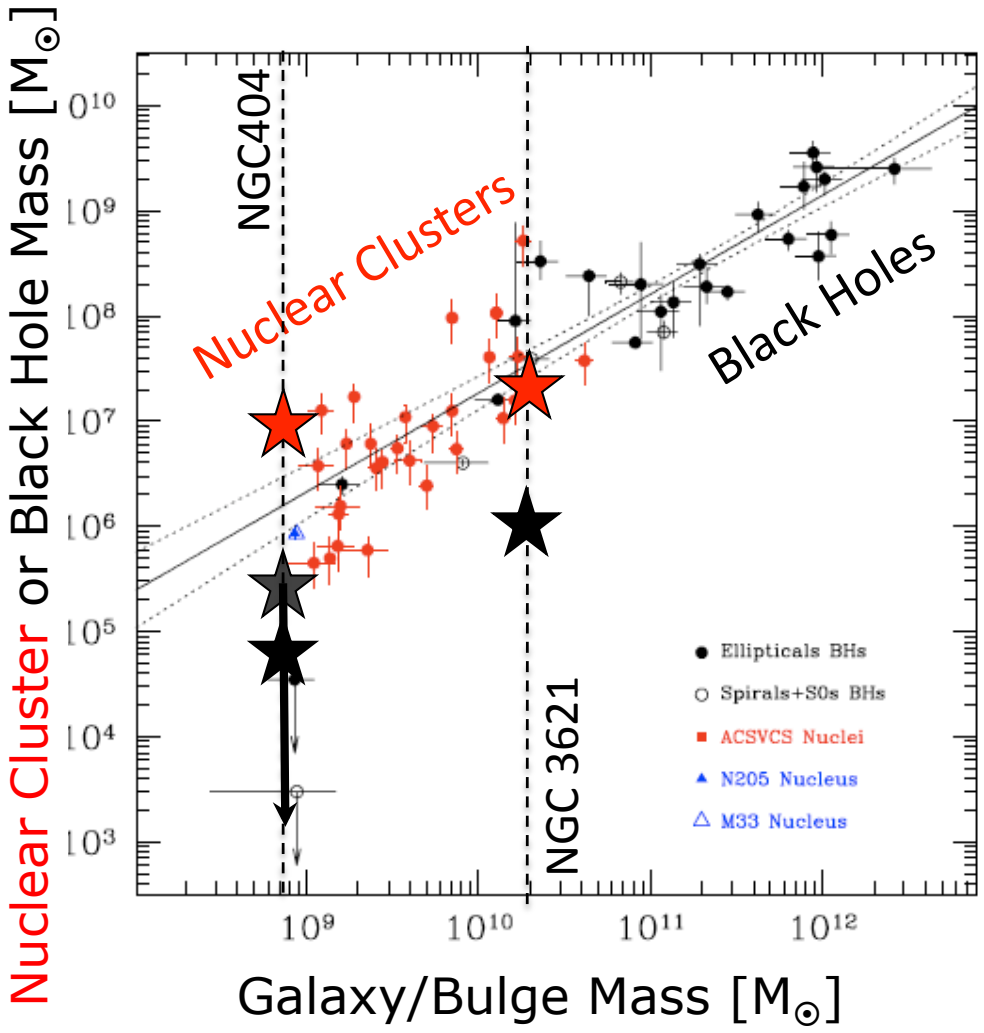
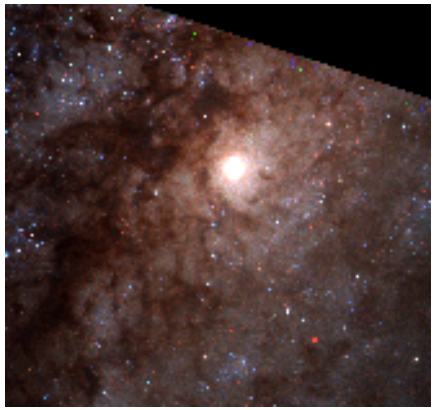
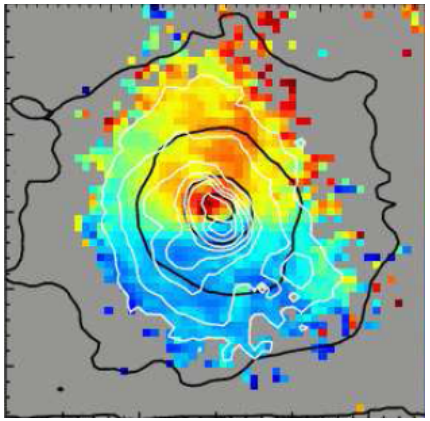


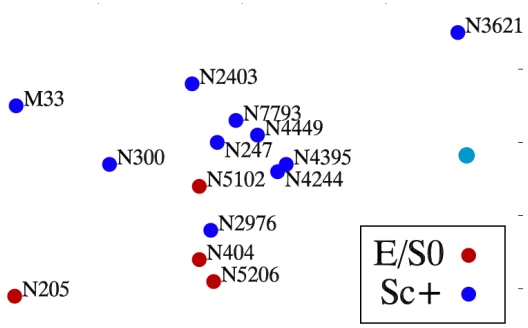

Ferrarese+ 2006

- Probing below the mass of previously detected black holes.
- Nuclear star clusters more massive than black holes.
- What mass to plot on x-axis?

# Summary








- Nuclear star clusters are common
- They co-exist with black holes
- Mixed evidence for a black hole in NGC404
- Detection of a black hole in NGC3621
- More to come!